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The effects of Tai Chi exercise on motor functions in mild-to-moderate Parkinson's disease

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ABSTRACT

Aims: Motor symptoms of Parkinson's disease (PD) adversely impact patients' quality of life. Exercise and physical therapy are important in reducing disability and increasing the quality of life in patients. Data on which type of exercise is more effective in the management of the disease is controversial. We aimed to examine the effect of Tai Chi exercises on motor functions in patients with PD and compare them with classical stretching-strengthening exercises.

Methods: This study comprised 51 participants with PD. The patients were divided into 3 groups as the Tai Chi group, the strengthening-stretching exercises group, and the control group. The first 2 groups exercised for 50 minutes 3 days a week for 12 weeks. Berg Balance Scale (BBS), The Timed Up and Go test, The freezing of Gait Questionnaire and the 10-meters walk test (10 MWT) were applied to 3 groups at the beginning and end of the study.

Results: The mean BBS scores of the Tai Chi group were higher than those of the control group. The mean timed up and go test and 10 MWT scores of the Tai Chi group were lower than those of the control group.

Conclusion: Tai Chi exercises can be an adjunctive treatment method for improving motor functions in patients with PD, as they are easy to apply, have high patient compliance and do not show serious side effects.

Keywords: Parkinson's disease, exercise, Tai Chi, quality of life

INTRODUCTION

Parkinson's disease (PD) is a neurodegenerative disorder marked by dopaminergic cell loss in the substantia nigra, disrupting cortico-striatal networks. These networks are essential for the regulation of cognitive functions and movement. The disease's prevalence increases with age, with a mean age of onset of 50–60 years. PD is distinguished by both motor and non-motor symptoms.[1]

The quality of life is significantly impacted by both sorts of illnesses. Nevertheless, the motor symptoms resulting from physical handicaps significantly impaire the patient's capacity to carry out their daily life tasks. As the condition advances, patients have a decline in postural stability and encounter balance difficulties. For this reason, especially in elderly patients, frequent falls and associated complications reduce patients' quality of life and life expectancy and increase health expenditures.[2]

Over time, non-medical therapies have been used to delay the course of PD, control symptoms, and lessen impairment. Previous studies investigating the relationship between PD and exercise have shown that exercises that include physical therapy methods such as strength training, aerobic training, Tai Chi or dance therapy delays the onset of symptoms and slows the disease progression.[3,4] Recent evidence indicates that exercise or physical therapy can effectively alleviate both motor and non-motor symptoms, thereby enhancing the quality of life for patients with PD.[3,5] In a review investigating various types of exercise, it was reported that exercises such as walking training, balance training, virtual reality interventions, Tai Chi and dance all create short-term beneficial effects, and their beneficial effects can continue in the long term.[6] Therefore, a safe and well-tolerated exercise program is a promising complementary therapy for preventing the development and delaying the progression of PD.

Although the neurobiological mechanisms underlying the impact of physical exercise on PD remain inconclusive, many hypotheses have been proposed. The prevailing consensus

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is that exercise prevents mitochondrial dysfunction and oxidative stress.[7-9] Exercise has been shown to be beneficial in PD by improving muscle flexibility and balance and positively influencing the patient's emotional state.[10] In addition, positron emission tomography showed increased blood flow in the basal ganglia and heightened activity in the cerebellum and motor regions of the brain during dance exercises.[11]

Classic stretching-strengthening exercises have been recommended and applied by physiotherapists to Parkinson's patients for years. It is stated that it increases the quality of life of patients and reduces the life difficulties caused by immobility.[12] In addition to classical physical therapy methods, Tai Chi is a mind-body exercise that combines breath control with continuous, curved, and spiraling body motions. Tai Chi exercises reduce stress and anxiety in adults, as well as improve aerobic capacity, muscle strength, balance and motor control.[13-17]

There is no clear answer as to which type of exercise may be more effective in improving motor functions in PD patients. In our study, we aimed to examine the effect of Tai Chi exercises on motor function in early Parkinson's patients and compare the efficacy of typical stretching–strengthening and Tai Chi exercises.

METHODS

Ethics

Sakarya University Faculty of Medicine Non-interventional Ethics Committee approved the study (Date: 27.11.2023, Decision No: 376). Throughout the study of the investigation, the researchers strictly followed the principles delineated in the Declaration of Helsinki.

Patients

This study was structured as a randomized controlled trial (RCT) encompassing 51 patients aged 50 to 80 diagnosed with idiopathic PD and monitored at the neurology outpatient clinic. The sample size was determined by calculating that 51 people needed to be contacted, with a 90% confidence level and an alpha level of.05.[18] Patients with Hoehn and Yahr stages 1-3 were included in the study. This staging system was developed in 1967 to easily define the severity of the disease for both the patient and clinician and to evaluate its progression. Stages 1 and 2 are classified as 'mild,' stage 3 as 'moderate,' and stages 4 and 5 as 'severe'.[19]

In order to guarantee that patients' characteristics were balanced, they were randomly assigned to one of three categories through computer-assisted block randomization.

Group 1 (n=18): Patients performing Tai Chi exercises,

Group 2 (n=17): Patients performing strengthening and stretching exercises,

Group 3 (n=16): Control group (no home exercises).

Randomization was conducted by a research assistant who was blinded to the study, ensuring unbiased group allocation.

Intervention

Patients in Groups 1 and 2 followed a prescribed home exercise program supervised by a physical therapist. Over 12 weeks, these patients performed their respective activities for 50 minutes three days a week. Group 1 engaged in Tai Chi exercises, while group 2 performed strengthening and stretching exercises. Both groups were monitored weekly via phone calls to ensure adherence. Patients in the control group (group 3) did not participate in any exercise program but were reassessed after 12 weeks.

Data Collection

Demographic information and medical records were obtained from the hospital's automation system by the attending physician. Motor assessments were conducted at the beginning and end of the study by a physical therapist.

Inclusion Criteria

Aged between 50 and 80 years,

Diagnosed with idiopathic PD,

Hoehn and Yahr stages 1-3,

Receiving ongoing medical treatment for PD without any changes in the last three months,

No physical therapy or exercise programs in the past three months,

Able to participate in a supervised 12-week Tai Chi or standard home exercise program.

Exclusion Criteria

Secondary parkinsonism,

Neurological or orthopedic conditions that could impair participation in the exercise program,

Advanced heart disease (aortic stenosis, atrial fibrillation, or pacemaker) or lung disease,

Visual or auditory impairments that could affect participation in the exercise program.

Clinical Evaluation

The participants' balance scores were obtained using the Berg Balance Scale (BBS). The BBS is a test that consists of 14 items and measures the dynamic balance of patients. Items are scored between 0 and 4 (0 represents the poorest performance and 4 signifies optimal performance). The maximum score that can be obtained is 56, with higher scores indicating better balance.[20]

The functional mobility of participants in the randomized groups was assessed using the Timed Up and Go test (TUGT). The patients were instructed to rise from their chairs, walk three meters, then return to their seats. The duration was measured in seconds.[21] The patient is at a low risk of collapsing and is able to walk independently if the time interval is 10 seconds or less. If the duration exceeds 30 seconds, it suggests that there is a high risk of collapsing and an occasional need

for assistance. This is due to the fact that results exceeding 11.5 seconds have been associated with a high fall risk in Parkinson's patients.[22]

The freezing of gait questionnaire (FOG-Q) consists of 6 items and was used to evaluate freezing episodes and severity. A score between 0 and 4 is given for each item. Of these 6 items, 4 assess freezing in general and 2 assess freezing during walking. High scores indicate severe freezing-of-gait attacks.[23]

The 10-metre walk test (10 MWT) was used to evaluate the patients' walking abilities. This test is easy to apply in Parkinson's patients and measures changes in walking speed. First, the patient's normal walking speed is recorded in m/s. The initial 2 meters of walking are considered the acceleration phase and the last 2 meters the deceleration phase, with measurements being made on a 14 meter-long track.[24] All assessments were conducted twice for each participant across the three randomized groups: at baseline (prior to starting the intervention) and after the 12-week exercise program. These standardized measures ensured consistency and allowed for the evaluation of intervention effects between the Tai Chi group, the strengthening and stretching group, and the control group.

Statistical Analysis

IBM SPSS Statistics 27 was employed to conduct the statistical analysis. The Shao method was employed to analyze the data's normality distribution.[25] The data were regularly distributed, with skewness and kurtosis values ranging from -1.5 to +1.5. Parametric tests were used because the data were normally distributed. Since there were 3 groups in total, the differences between the pre- and post-exercise groups were evaluated using one-way analysis of variance (ANOVA) test. For comparison of pre- and post-treatment means, repeated measures ANOVA was used. Therefore, the differences between the groups before and after the exercises could be evaluated using a ANOVA test. Homogeneity between groups was assessed using Levene's test, which resulted in an $\alpha>0.05$, indicating a homogeneous distribution. Next, the direction of the difference between the paired groups in the BBS, FOG-Q, TUGT and 10 MWT was examined using the Tukey post-hoc test. The Pearson Chi-square significance test was used to determine the relationship between the variables based on the underlying assumptions.

RESULTS

There were 30 female, and 21 male individuals diagnosed with PD included in the study. The demographic characteristics of the study participants are shown in **Table 1**. The patients were divided into 2 exercise groups (stretching strengthening and Tai Chi) and 1 control group.

Variance analysis ANOVA was employed to assess the differences among groups. There was no significant difference between the stretching strengthening, Tai Chi and control groups in terms of BBS, FOG-Q, TUGT and 10 MWT before exercise ($p>0.05$ for all) (**Table 2**).

Repeated Measures ANOVA test was used to compare the 3 groups before and after treatment. Within group comparison showed that the patients' BBS scores increased after exercise, while their TUGT and 10 MWT scores decreased (p=0.004, 0.000, 0.001, respectively). However, no significant difference was observed in the FOG-Q scores before and after exercise (p=0.174) (**Table 3**).

Table 1. Participants' demographic information

		n	%
Gender	Female	30	58.8
	Male	21	41.2
Marital status	Married	37	72.5
	Single	2	3.9
	Widow	11	21.6
Alcohol use	Yes	0	0
	No	51	100
Smoking	Yes	5	9.8
	No	46	90.2
Education status	Illiterate	4	7.8
	Primary school	33	64.7
	High school	10	19.6
	University	4	7.8

*A frequency test was performed using the SPSS program to analyze the participants' descriptive information

Table 2. The difference between the pre-exercise BBS, FOG-Q, TUGT, and 10 MWT scores of the stretching strengthening, Tai Chi and control groups

	F	p
BBS	0.137	0.872
FOG-Q	0.836	0.439
TUGT	1.249	0.296
10 MWT	1.245	0.297

BBS: Berg Balance Scale, FOG-Q: Freezing of Gait Questionnaire, TUGT: Timed Up and Go test, 10 MWT: 10-metre walk test
*Analysis of variance ANOVA was used to test the difference between groups

It was observed that the patients' BBS scores increased after exercise compared to before exercise, while their TUGT and 10 MWT scores decreased (p=0.004, 0.000, 0.001, respectively). However, no significant difference was observed in the FOG-Q scores before and after exercise (p=0.174) (**Table 3**).

There was no statistically significant difference between the BBS, FOG-Q, TUGT and 10 MWT scores before and after the exercise period according to gender (**Table 4**).

Given the homogeneous distribution of the data, the directional differences between the matched groups in BBS, FOG-Q, TUGT, and 10 MWT were analyzed using the Tukey Post-Hoc test. The average BBS scores of the Tai-Chi group exceeded those of the control group ($p<0.05$). The average TUGT and 10 MWT scores of the Tai-Chi group were inferior to those of the control group ($p<0.05$) (**Table 5**).

DISCUSSION

The PD patients in our study were evaluated before and after exercise, and it was observed that the BBS, TUGT and 10 MWT scores significantly improved after 12 weeks of exercise therapy. As a result, we may infer that short-term exercise improves balance function, lowers the chance of falling, and increases walking speed in PD patients. Although we have a low patient population to generalize the findings, patients who exercise regularly under expert supervision show better motor functions.

It was observed that the FOG-Q scores of the patients were similar before and after exercise. Longer and regular

Table 3. Participants' pre- and post-exercise BBS, FOG-Q, TUGT and 10 MWT scores

		Pre-exercise			Post-exercise			
	n	Min	Max	X±SD	Min	Max	X±SD	p
BBS	51	16.00	56.00	38.72±11.55	18.00	65.00	42.35±12.77	0.004*
FOG-Q	51	0.00	23.00	9.74±6.86	00.00	41.00	8.80±8.04	0.174
TUGT	51	10.00	39.00	18.54±6.46	8.00	42.00	16.41±6.90	0.000*
10 MWT	51	29.00	153.00	54.41±21.81	24.00	160.00	49.09±22.70	0.001*

BBS: Berg Balance Scale, FOG-Q: Freezing of Gait Questionnaire, TUGT: Timed Up and Go test, 10 MWT: 10-metre walk test, Min: Minimum, Max: Maximum, SD: Standard deviation
*Repeated measures ANOVA test was used to compare the 3 groups pre- and post-exercises

Table 4. Comparison of BBS, FOG-Q, TUGT and 10 MWT scores before and after exercise between genders

	Before exercise			After exercise		
Test	Female (30)	Male (21)	p	Female (30)	Male (21)	p
BBS	42.89±10.66	36.20±15.65	0.081	43.44±11.96	38.55±16.70	0.237
FOG-Q	9.34±7.13	10.30±7.34	0.651	7.55±7.15	8.85±7.04	0.533
TUGT	18.68±7.48	17.20±4.79	0.437	16.58±7.40	15.25±5.27	0.491
10 MWT	47.10±2.92	47.20±13.40	0.980	41.93±11.46	42.95±14.12	0.782

BBS: Berg Balance Scale, FOG-Q: Freezing of Gait Questionnaire, TUGT: Timed Up and Go test, 10 MWT: 10-metre walk test
*Independent samples t-Test was used to compare other parameters according to gender before and after exercise

Table 5. Comparison of post-exercise BBS, FOG-Q, TUGT and 10 MWT scores between stretching-strengthening, tai chi and control groups

Test	Group	n	mean	SD	F	p	Tukey
BBS	Tai Chi (1)	18	46.61	12.50	4.044	0.024*	1>3
	Stretching–strengthening (2)	17	44.41	12.36			
	Control (3)	16	35.37	11.21			
TUGT	Tai Chi (1)	18	13.00	3.58	5.760	0.006*	3>1
	Stretching–strengthening (2)	17	16.29	6.04			
	Control (3)	16	20.37	8.63			
10 MWT	Tai Chi (1)	18	39.38	10.53	4.093	0.023*	3>1
	Stretching–strengthening (2)	17	48.70	19.49			
	Control (3)	16	60.43	30.61			

BBS: Berg Balance Scale, FOG-Q: Freezing of Gait Questionnaire, TUGT: Timed Up and Go test, 10 MWT: 10-metre walk test, SD: Standard deviation
*Since the data were homogeneously distributed, the direction of the difference between the paired groups in BBS, FOG-Q, TUGT and 10 MWT was examined with the Tukey Post-Hoc test

exercise programs may be more effective in affecting freezing symptoms and disease severity. In our study, the exercise program given to the patients in a short period of time may not have affected these long-term symptoms.

Over the past 30 years, studies have shown that exercise can protect against PD, with some studies stating that this protective effect is higher in men than in women.[26,27] In a publication on Tai Chi, it was reported that Tai Chi exercises were more beneficial for low-educated women.[28] Building on these findings, we also investigated whether there was a gender difference in the effect of short-term exercise on PD patients. We observed that the well-being of the patients after the exercise program did not discriminate between genders. Our study was conducted with a small patient group, and we anticipate that studies with large patient series that will also consider gender and age distributions will shed light on this issue.

A meta-analysis that evaluated the impact of various forms of physical exercise on the severity of motor symptoms and quality of life in adults with PD. It was observed that the evidence regarding the effects of stretching-strengthening training is still ambiguous. No significant side effects were documented in any of the studies as a consequence of the meta-analysis. In the review of PD patients, there was evidence of beneficial effects for the majority of physical exercise types. However, there was minimal evidence of differences between the varieties of exercise.[29] In another meta-analysis, consistent evidence was discovered to suggest that Tai Chi is a relatively safe program that results in improvements in bradykinesia and balance, as well as increased overall motor function. Nevertheless, no statistically significant advantages were observed in terms of functional mobility or quality of life. Accordingly, it was determined that additional investigation is required regarding this matter.[30] In another study, older adult patients with mild cognitive impairment were followed for 36 weeks and performed Tai Chi exercises, and it was concluded that their cognitive functions were better compared to the other group doing fitness walking.[28] In addition, Tai Chi exercises have been shown to have positive effects on psychiatric diseases such as depression and anxiety disorders.[31] Tai Chi exercises seem promising in PD, which is a disease that is frequently accompanied by cognitive and psychiatric symptoms.

At the end of our study, we found that the BBS scores were lower and the TUGT and 10 MWT scores were higher in the Tai Chi exercise group compared to the control group after a 12-week exercise program. These results could be interpreted as showing that patients have better balance and walking functions after Tai Chi exercises and that their risk of falling is reduced. Notably, no statistically significant benefits were observed in the patient group who performed stretching–strengthening exercises.

Limitations
The limitations of our study include the small patient group, short exercise duration, and not including the patients' treatment protocols in the study.

CONCLUSION
Tai Chi exercises can be an adjunctive treatment method in improving motor functions in PD patients, as they are easy to apply, can be done at home by themselves, exhibit high patient compliance and do not show serious side effects. Multicenter studies with longer follow-up periods and larger patient series on this subject will contribute to the existing literature.

ETHICAL DECLARATIONS
Ethics Committee Approval
Sakarya University Faculty of Medicine Non-interventional Ethics Committee approved the study (Date: 27.11.2023, Decision No: 376).

Informed Consent
All patients signed and free and informed consent form.

Referee Evaluation Process
Externally peer- reviewed.

Conflict of Interest Statement
The authors have no conflicts of interest to declare.

Financial Disclosure
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Author Contributions
All the authors declare that they have all participated in the design, execution, analysis of the paper and that they have approved the final version.

REFERENCES
1. Costa HN, Esteves AR, Empadinhas N, Cardoso SM. Parkinson's disease: a multisystem disorder. *Neurosci Bull*. 2023;39(1):113-124. doi:10.1007/s12264-022-00934-6
2. Li F, Harmer P, Fitzgerald K, et al. Tai Chi and postural stability in patients with Parkinson's disease. *N Engl J Med*. 2012;366(6):511-519. doi:10.1056/NEJMoa1107911
3. Mak MK, Wong-Yu IS, Shen X, Chung CL. Long-term effects of exercise and physical therapy in people with Parkinson disease. *Nat Rev Neurol*. 2017;13(11):689-703. doi:10.1038/nrneurol.2017.128
4. Cheng FY, Yang YR, Chen LM, Wu YR, Cheng SJ, Wang RY. Positive effects of specific exercise and novel turning-based treadmill training on turning performance in individuals with Parkinson's disease: a randomized controlled trial. *Sci Rep*. 2016;13(6):33242. doi:10.1038/srep 33242
5. Reynolds GO, Otto MW, Ellis TD, Cronin-Golomb A. The therapeutic potential of exercise to improve mood, cognition, and sleep in Parkinson's disease. *Mov Disord*. 2016;31(1):23-38. doi:10.1002/mds.26484
6. Mak MKY, Wong-Yu ISK. Exercise for Parkinson's disease. *Int Rev Neurobiol*. 2019;147:1-44. doi:10.1016/bs.irn.2019.06.001
7. Ascherio A, Schwarzschild MA. The epidemiology of Parkinson's disease: risk factors and prevention. *Lancet Neurol*. 2016;15(12):1257-1272. doi:10.1016/S1474-4422(16)30230-7
8. Boulos C, Yaghi N, El Hayeck R, Heraoui GN, Fakhoury-Sayegh N. Nutritional risk factors, microbiota and Parkinson's disease: what is the current evidence? *Nutrients*. 2019;11(8):1896. doi:10.3390/nu11081896
9. Cardoso SM, Empadinhas N. The microbiome-mitochondria dance in prodromal Parkinson's disease. *Front Physiol*. 2018;9(9):471. doi:10.3389/fphys.2018.00471
10. Xu X, Fu Z, Le W. Exercise and Parkinson's disease. *Int Rev Neurobiol*. 2019;147:45-74. doi:10.1016/bs.irn.2019.06.003
11. Hashimoto H, Takabatake S, Miyaguchi H, Nakanishi H, Naitou Y. Effects of dance on motor functions, cognitive functions, and mental symptoms of Parkinson's disease: a quasi-randomized pilot trial. *Complement Ther Med*. 2015;23(2):210-219. doi:10.1016/j.ctim.2015.01.010
12. Kaya K, Ozel S. Parkinson hastalığı rehabilitasyonu. *Turkish J Geriatr*. 2008;12(1):36-48
13. Li G, Huang P, Cui SS, et al. Mechanisms of motor symptom improvement by long-term Tai Chi training in Parkinson's disease patients. *Transl Neurodegener*. 2022;11(1):6. doi:10.1186/s40035-022-00280-7
14. Zhu M, Zhang Y, Pan J, Fu C, Wang Y. Effect of simplified Tai Chi exercise on relieving symptoms of patients with mild to moderate Parkinson's disease. *J Sports Med Phys Fitness*. 2020;60(2):282-288. doi:10.23736/S0022-4707.19.10104-1
15. Hackney ME, Earhart GM. Tai Chi improves balance and mobility in people with Parkinson disease. *Gait Posture*. 2008;28(3):456-460. doi:10.1016/j.gaitpost.2008.02.005
16. Yang Y, Hao YL, Tian WJ, et al. The effectiveness of Tai Chi for patients with Parkinson's disease: study protocol for a randomized controlled trial. *Trials*. 2015;16(1):111. doi:10.1186/s13063-015-0639-8
17. Li F, Harmer P, Liu Y, et al. A randomized controlled trial of patient-reported outcomes with Tai Chi exercise in Parkinson's disease. *Mov Disord*. 2014;29(4):539-545. doi:10.1002/mds.25787
18. Yazıcıoğlu Y, Erdoğan S. SPSS uygulamalı bilimsel araştırma yöntemleri. Ankara: Detay Yayıncılık; 2004.
19. Goetz CG, Poewe W, Rascol O, et al. Movement disorder society task force on rating scales for Parkinson's disease. Movement disorder society task force report on the Hoehn and Yahr staging scale: status and recommendations. *Mov Disord*. 2004;19(9):1020-1028. doi:10.1002/mds.20213
20. Sahin F, Yilmaz F, Ozmaden A, et al. Reliability and validity of the Turkish version of the Berg balance scale. *J Geriatr Phys Ther*. 2018;31(1):32-37. doi:10.1007/s10882-017-9584-7
21. Podsiadlo D, Richardson S. The Timed Up and Go: a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*. 1991;39(2):142-148. doi:10.1111/j.1532-5415.1991.tb01616.x
22. Nocera JR, Stegemöller EL, Malaty IA, Okun MS, Marsiske M, Hass CJ. Using the Timed Up & Go test in a clinical setting to predict falling in Parkinson's disease. *Arch Phys Med Rehabil*. 2013;94(7):1300-1305. doi:10.1016/j.apmr.2013.02.020
23. Giladi N, Shabtai H, Simon ES, et al. Construction of freezing of gait questionnaire for patients with parkinsonism. *Parkinsonism Relat Disord*. 2000;6(3):165-170. doi:10.1016/s1353-8020(99)00062-0
24. Duncan RP, Combs-Miller SA, McNeely ME, et al. Are the average gait speeds during the 10 meter and 6 minute walk tests redundant in Parkinson disease? *Gait Posture*. 2017;52:178-182. doi:10.1016/j.gaitpost.2016.11.033
25. Zhou M, Shao Y. A Powerful Test for Multivariate Normality. *J Appl Stat*. 2014;41(2):351-363. doi:10.1080/02664763.2013.839637
26. Yang F, Trolle Lagerros Y, Bellocco R, et al. Physical activity and risk of Parkinson's disease in the Swedish National March Cohort. *Brain*. 2015;138(2):269-275. doi:10.1093/brain/awu323
27. LaHue SC, Comella CL, Tanner CM. The best medicine? The influence of physical activity and inactivity on Parkinson's disease. *Mov Disord*. 2016;31(10):1444-1454. doi:10.1002/mds.26728
28. Chen Y, Qin J, Tao L, et al. Effects of Tai Chi Chuan on Cognitive function in adults 60 years or older with type 2 diabetes and mild cognitive impairment in China: a randomized clinical trial. *JAMA Netw Open*. 2023;6(4):e237004. doi:10.1001/jamanetworkopen.2023.7004
29. Ernst M, Folkerts AK, Gollan R, et al. Physical exercise for people with Parkinson's disease: a systematic review and network meta-analysis. *Cochrane Database Syst Rev*. 2023;1(1):CD013856. doi:10.1002/14651858.CD013856.pub2

30. Yu X, Wu X, Hou G, et al. The impact of Tai Chi on motor function, balance, and quality of life in Parkinson's disease: a systematic review and meta-analysis. *Evid Based Complement Alternat Med*. 2021;2021: 6637612. doi:10.1155/2021/6637612
31. He G, Zhang X, Yan T, et al. The efficacy of Tai Chi for depression: a protocol for systematic review and meta-analysis. *Medicine (Baltimore)*. 2022;101(5):e28330. doi:10.1097/MD.0000000000028330